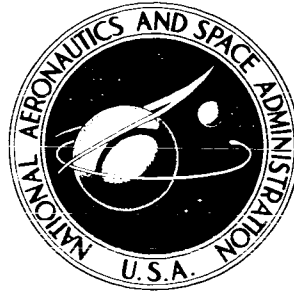


NASA TECHNICAL  
MEMORANDUM

NASA TM X-942

12g.



CTS: \$ 0.00

(NASA TM X-942)

N64-15921  
wde-1

VIBRATION ISOLATION OF  
SATELLITE TAPE RECORDERS

by Joseph H. Conn

Goddard Space Flight Center  
Greenbelt, Maryland

NASA

orpe

**VIBRATION ISOLATION OF  
SATELLITE TAPE RECORDERS**

**By Joseph H. Conn**

**Goddard Space Flight Center  
Greenbelt, Maryland**

**NATIONAL AERONAUTICS AND SPACE ADMINISTRATION**

---

**For sale by the Office of Technical Services, Department of Commerce,  
Washington, D.C. 20230 -- Price \$0.50**

# VIBRATION ISOLATION OF SATELLITE TAPE RECORDERS

by

Joseph H. Conn

*Goddard Space Flight Center*

## SUMMARY

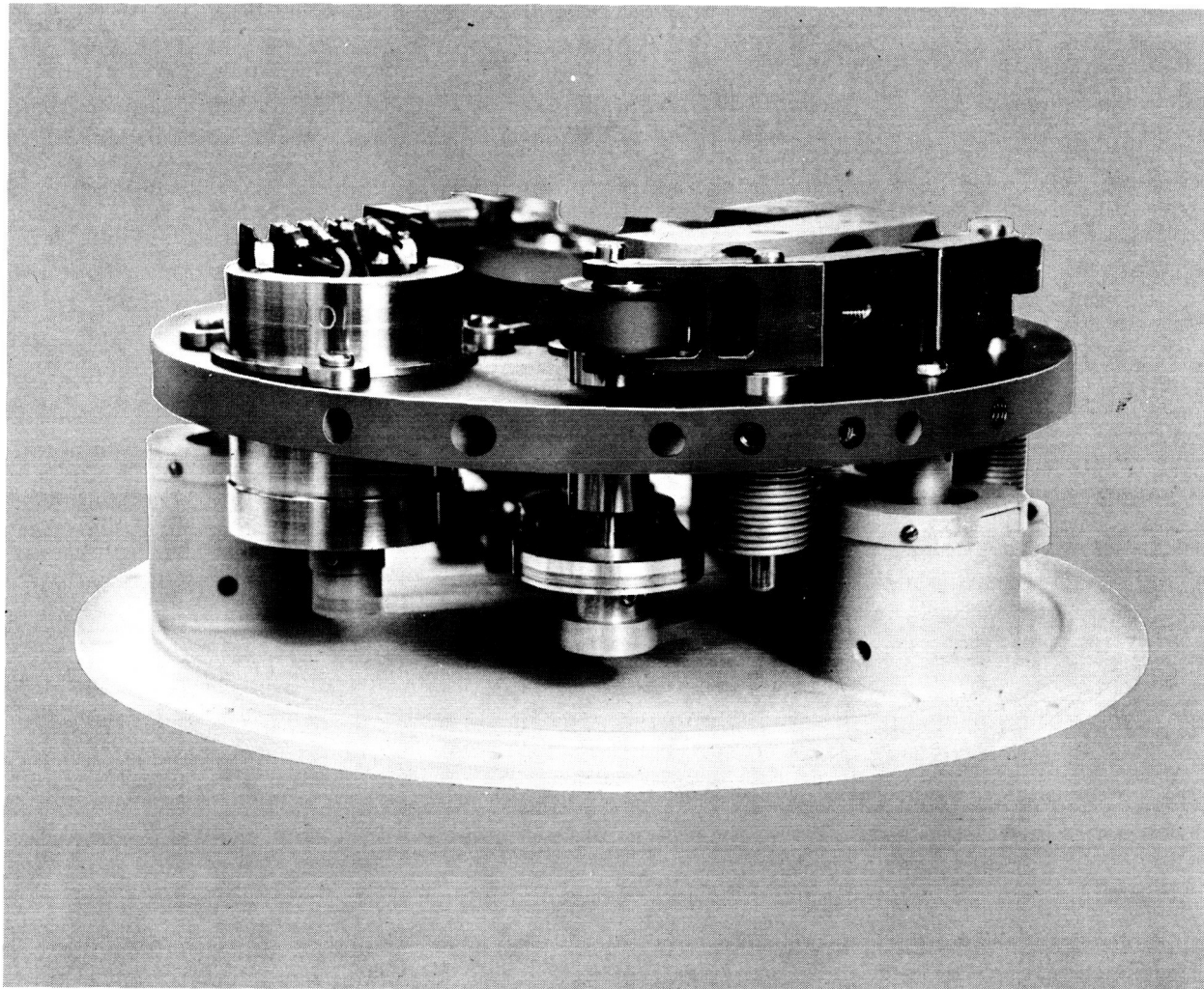
15 921 2 11  
A standardized method of shock and vibration isolation for satellite tape recorders has been developed. Using readily available components, the isolators combine small size, light weight, and damping characteristics with good load-carrying and elastomeric properties. This system is now being used in the International Satellite UK-2 and will be used in the Orbiting Solar Observatory (S-57 model). It may, however, be applied to many other components, such as electron tubes, bearing assemblies, and sensitive electronic assemblies.

*Author*

## CONTENTS

Summary . . . . .	i
Frontispiece . . . . .	iv
INTRODUCTION . . . . .	1
DESIGN CONSIDERATIONS . . . . .	1
ISOLATOR SELECTION . . . . .	3
TAPE RECORDER ISOLATOR DESIGN . . . . .	4
RESULTS . . . . .	7
CONCLUSION . . . . .	7





Frontispiece—The International Satellite (UK-2) tape recorder and isolator system.

# VIBRATION ISOLATION OF SATELLITE TAPE RECORDERS

(Manuscript Received July 8, 1963)

by

Joseph H. Conn

*Goddard Space Flight Center*

## INTRODUCTION

The early tape recorders designed for NASA satellite applications had extremely low survival rates when subjected to satellite design vibration tests. The majority of the failures could be accounted for in the following ways: (1) The high dynamic acceleration levels in the medium and high frequency ranges caused surface fatigue of the bearings in the motors and capstan housing. (2) When the pinch roller assemblies resonated, the acceleration loads were so great that tension would be released from the tape causing it to loop and occasionally to tangle.

As the development of the satellite recorder progressed toward standardization of components, it was apparent that a vibration isolation system should also be designed, if possible, with standard, readily available components. A standardized recorder and standardized mounting hardware would allow greater design flexibility and permit interchange between programs.

The first approach to the vibration problem was to increase the design load requirements on the bearings and springs of the recorder. However, this was impractical because the technological and material requirements were too stringent. The bearing assemblies became impossible to standardize because of the constantly changing loads. Furthermore, increased preload requirements on the pinch roller springs increased their physical dimensions. The preload also increased the drag torque on the drive system, requiring an increase in both motor sizes and power requirements. It became apparent that the tape recorder would have to have a filter for the environment which it experienced. A shock and vibration isolator was carefully selected which had a low resonance frequency and was compatible in size with the tape recorders.

## DESIGN CONSIDERATIONS

The particular design discussed here was used in the International Satellite UK-2. A similar design is being used in the Orbiting Solar Observatory S-57. The UK-2 tape recorder shown in Figure 1 was the first commercial modularized tape recorder designed by the Recording Techniques Section at

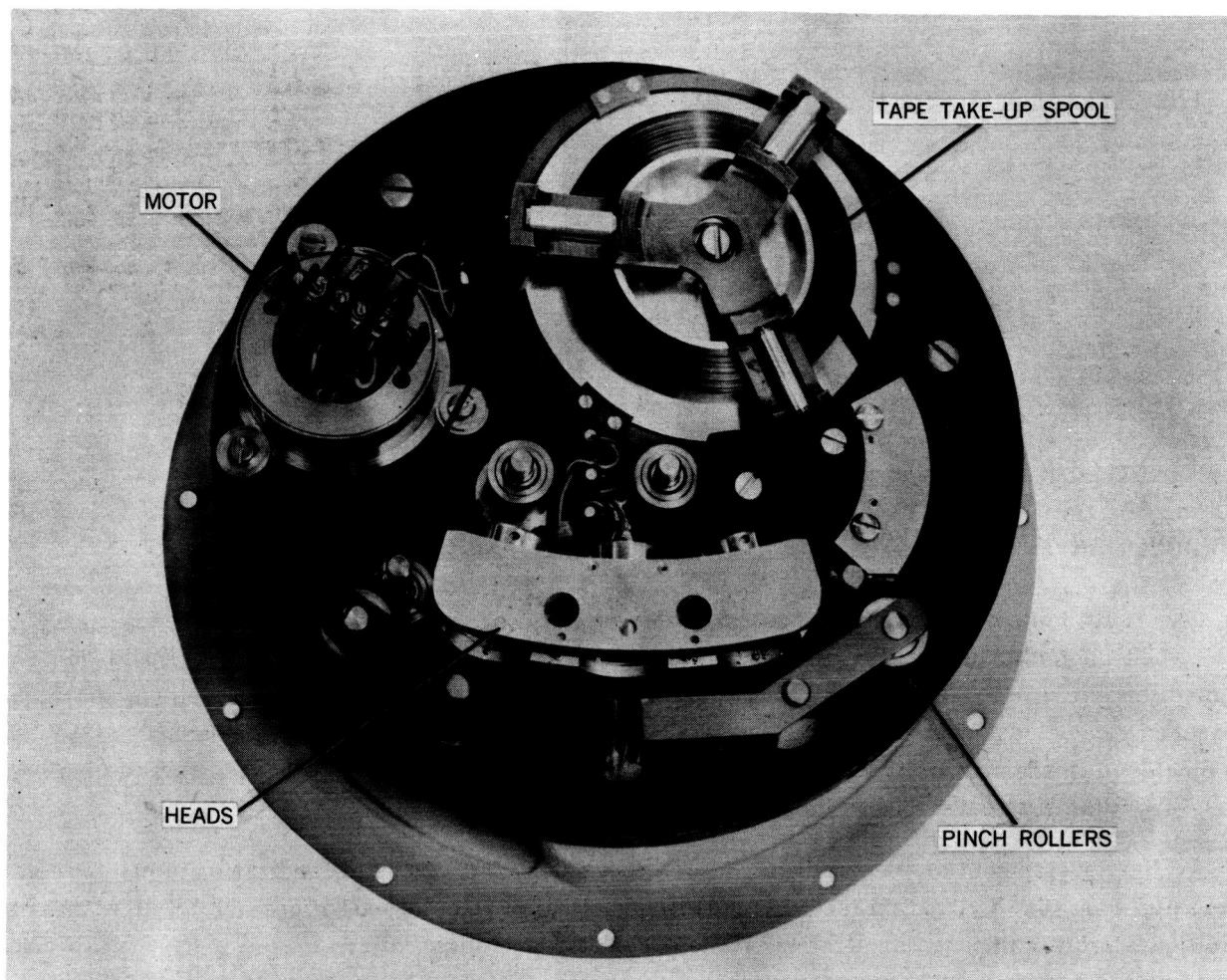


Figure 1—UK-2 tape recorder.

Table 1  
Design Vibration Levels for UK-2

Vibration Axis	Frequency Range (cps)*	Level
Thrust Z-Z	5-50	±2.3 g
	50-75	0.072 D. A.
	75-150	±21.0 g
	150-500	±10.0 g
	500-2000	±21.0 g
Lateral X-X and Lateral Y-Y	5-50	±0.9
	50-500	±2.1
	500-2000	±4.2

\*The time rate of change of frequency is proportional to the frequency at the rate of 2 octaves per minute.

GSFC. The complete tape recorder is enclosed in an envelope 7.00 inches in diameter and 3 inches in height with a total weight of 4 lb or less. The container is pressure-tight to eliminate bearing lubrication problems and motor arcing in a high vacuum environment. The UK-2 satellite was subjected to a vibration environment 1.5 times greater than the expected flight environment. However, since the satellite structure was a multidegree-of-freedom elastic body the input levels were amplified, the major amplification occurring at the structure's first mode. For 70 to 250 lb satellites the first mode usually occurs between 75 and 200 cps. Table 1 indicates the design or prototype vibration levels

for the tape recorder assembly. In addition to the sinusoidal levels, the recorder was subjected to Gaussian random vibration in the three orthogonal axes. These levels were of  $0.07 \text{ g}^2/\text{cps}$  power spectral density in the frequency band range of 20 to 2000 cps for a duration of 4 minutes. The flight vibration levels are approximately 30 percent less than the design vibration levels.

A further design specification considered was steady state accelerations. The tape recorder was subjected to an acceleration of 27 g's for prototype testing and 18 g's for flight levels. The 18 g acceleration level was the maximum expected in flight and occurred in the last few seconds of the X-248 rocket motor's burning period.

These specifications were used to test particular mounts for the resonance frequency, the amplification decay rate, and the maximum deflection. The flight level test results were used for evaluating the expected flight performance with respect to the combined effect of steady state accelerations and vibration. Since the isolator system would be exposed to only the individual prototype test levels when tested with the integrated spacecraft, the total maximum deflection for a combined test at these levels would not be significant.

## ISOLATOR SELECTION

The primary consideration in selecting an isolator is the frequency or frequency band to be isolated. In the particular design for spacecraft components the frequency of interest is the spacecraft's design parameter of 40 to 50 cps was selected for the isolator resonance. In addition, it was necessary to have a sufficient amount of damping in the mounts to control the amplification at isolator resonance and to insure a rapid decay rate afterward. Furthermore a nonlinear isolator was desirable. This would result in a shift in the apparent resonance frequency of the isolator as the load levels increase. By selecting an isolator system that would have a resonance just above 50 cps for the  $\pm 1.5 \text{ g}$ 's of the flight vibration levels and a resonance just below 50 cps for inputs of  $\pm 7 \text{ g}$ 's or more, the maximum acceleration would be somewhat lower than that of a simple resonance (Figure 2).

To accomplish this particular result an isolator with a decreasing spring constant  $K$  for an increasing stress level is required. In Figure 3 are shown four typical isolator deflection curves, one with an increasing  $K$ , one with a linear  $K$ , and two with a decreasing  $K$ . An elastic isolator can be designed to have any one of these characteristics. The first case (curve 1) results from compressive loading of the elastomer, the second (curve 2) from pure shear loading, and the third (curve 3) from pure tension loading. For a mount that has a characteristic of shear for light loads, tension for moderate loads, and compression for severe loads, an isolator with characteristics similar to those for curve 4 should be used. It should be noted, however, that the isolators function best when operating in the shear or linear area of the curve.

Before the final selection of an isolator can be made, a few additional design parameters must be considered. During flight the spacecraft is essentially a free body with a number of external and internal forces, causing side as well as thrust loads to be imparted to the isolator system. Therefore, the mounts must have good isolation properties in the transverse axis as well as in the thrust axis. Furthermore, the physical and chemical properties of the isolator must be unaffected by the

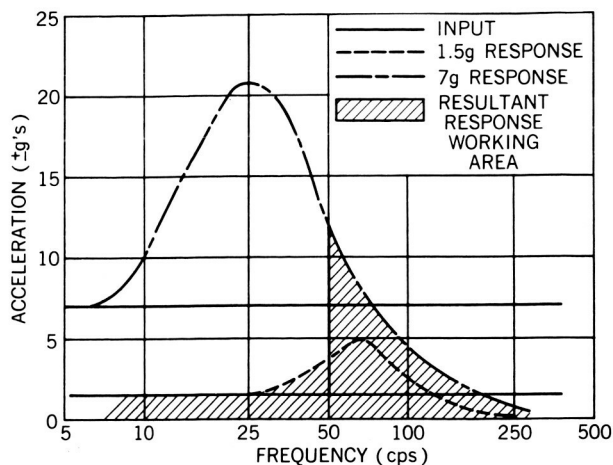


Figure 2—Ideal case, resonance shift at increased loads.

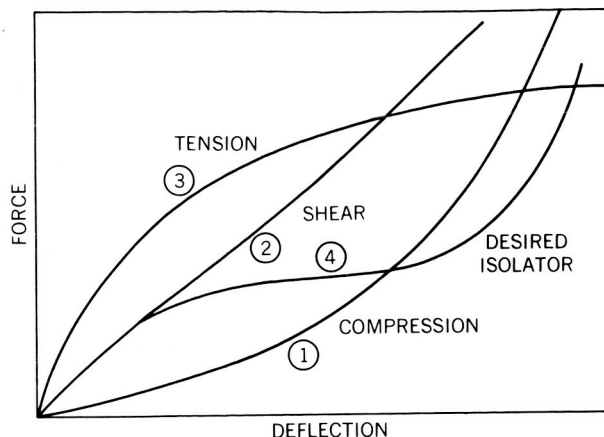


Figure 3—Elastomer deflection curves,  
 $K = \Delta \text{force} / \Delta \text{deflection}$ .

temperature requirements and the local environment. Finally, the physical arrangement and size of the isolators must be as simple as possible for the particular system.

## TAPE RECORDER ISOLATOR DESIGN

From these design considerations a particular system was proposed for testing. The choice of vibration isolators was limited because of the following requirements:

1. Relatively small size.
2. Good load-carrying properties.
3. Decreasing resonance frequency with increasing stress.

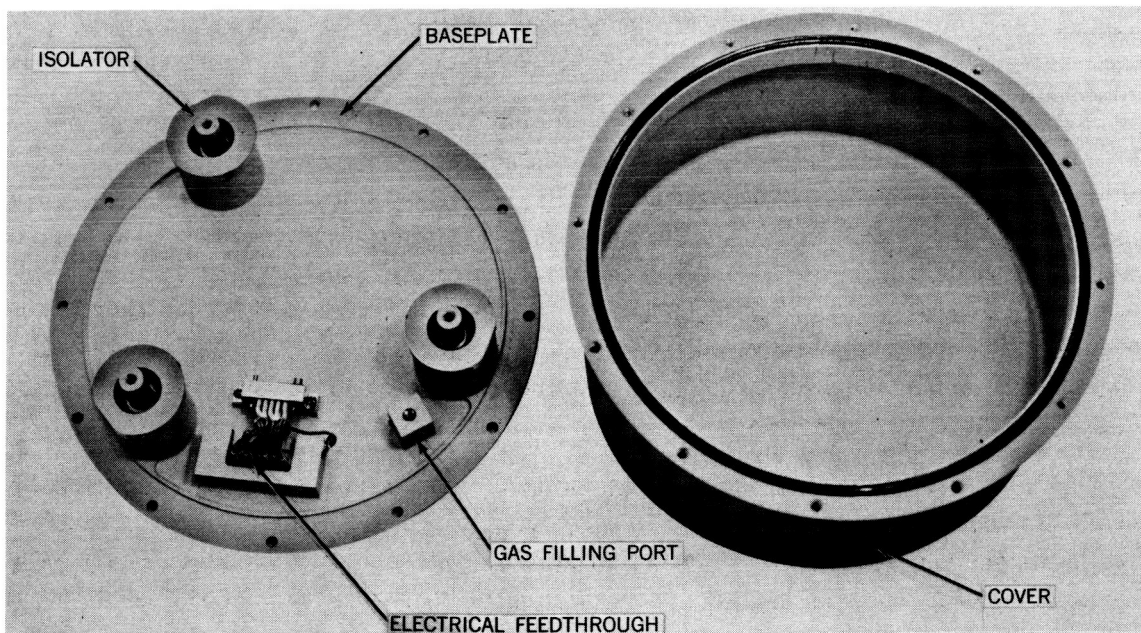


Figure 4—Tape recorder container and isolator system.



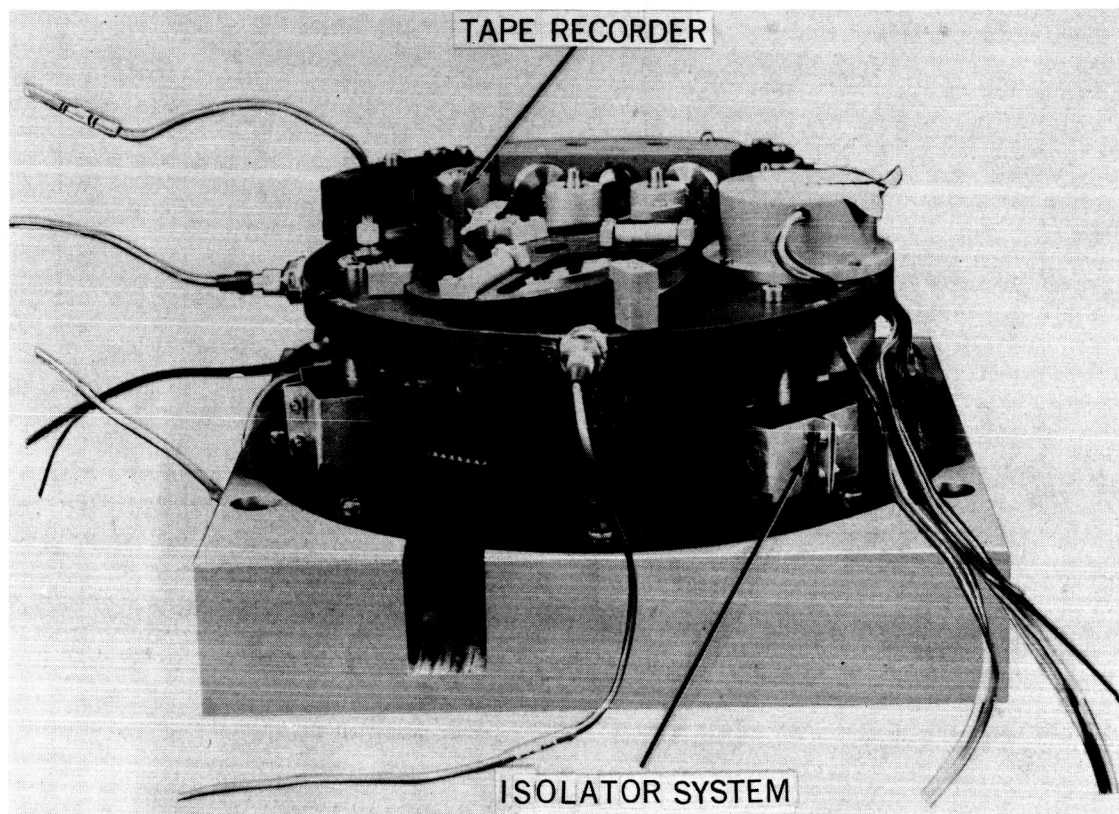


Figure 5—Vibration test setup.

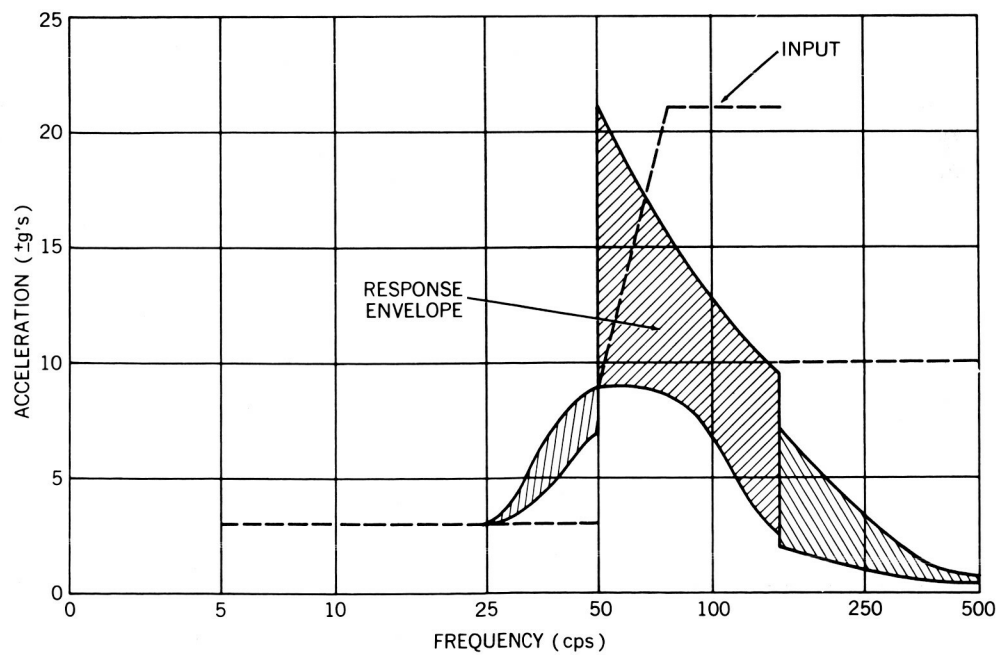


Figure 6—Tape recorder prototype response, thrust axis.

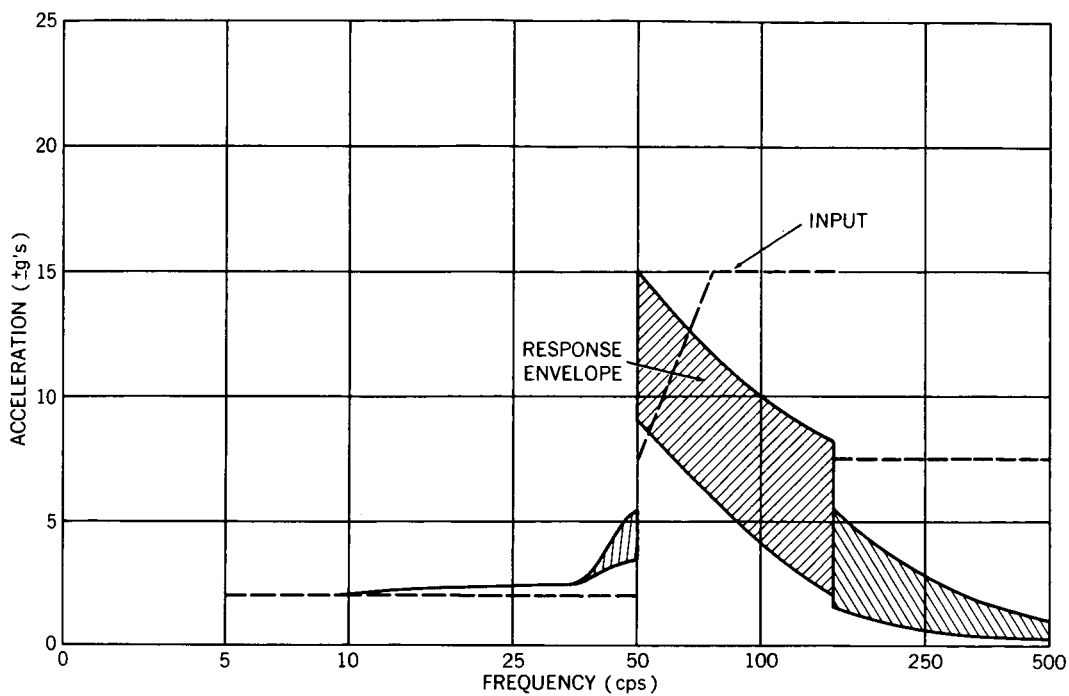


Figure 7—Tape recorder flight response, thrust axis.

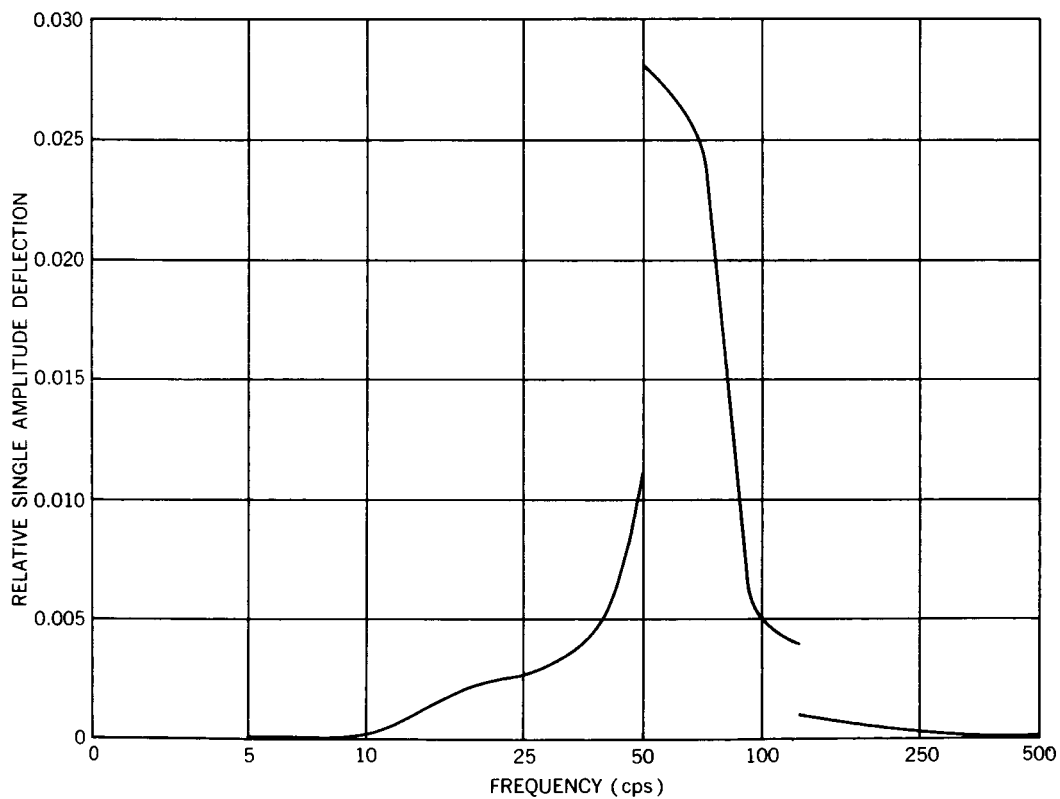


Figure 8—Tape recorder deflection, flight levels.

The particular mount chosen was a standard Loard shock and vibration mount of the HT-0 series. The isolator system (Figure 4) consisted of three mounts arranged to be as nearly symmetrical as allowable by the tape recorder transport configuration.

An engineering test system (Figure 5), using the desired arrangement and a number of standard mounts in the 2 and 3 lb load ranges, was assembled. This unit was used for selecting the proper load range of the mount and determining the deflection characteristics. A pre-prototype model of the container, incorporating the isolator housings into the cover, was then designed and fabricated. A decrease of the inside diameter of the mount housing from that of the standard housing was used to increase the friction damping and lower the amplification at 50 cps.

## RESULTS

During the preliminary vibration tests the 2 lb mount was selected as the most acceptable. The acceleration responses are described in Figures 6 and 7. The individual accelerometer outputs were enveloped to produce an overall picture of the maximum accelerations. Furthermore, the range of accelerations at any particular frequency shows the relative amount of rocking.

In Figure 8 the maximum relative deflection between the tape transport and the baseplate at flight levels is plotted. The minimum clearance envelope for the tape transport was determined from this plot plus the maximum deflection due to steady state acceleration. The final design clearance for all combined loads, with 100 percent safety factors, was only 0.25 inch. The final tests on the pre-prototype model of the tape recorder and container were performed at the design levels and at 3 times the flight levels. No failures of the tape recorder system resulted.

## CONCLUSION

As a result of the tape recorder's performance during all of its tests, future tape recorders will incorporate an isolation system. However, tape recorders are only one area of space satellites in which isolation can be used effectively. Other areas include electronics, electron tubes, mechanical mechanisms, and possibly the complete spacecraft.